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National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
SOUTHEAST FISHERIES SCIENCE CENTER
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MEMORANDUM

FOR: F/SER Roy Crabtree, Regional Administrator

FROM: F/SEC4 Nancy B. Thompson, Science Administrator

SUBJECT: Potential Impacts of Liquid Natural Gas Processing Facilities on Fishery Organisms in the Gulf of Mexico

This memorandum provides additional information on potential impacts of proposed Liquid Natural Gas (LNG) processing facilities in waters of the Gulf of Mexico. In a memo to you dated July 11, 2003, I provided some preliminary comments on Chevron's Draft EIS for the Port Pelican Deepwater Liquefied Natural Gas facility. Herein, the scientific staff of the Southeast Fisheries Science Center and the NOAA Center for Coastal Fisheries and Habitat Research provide a review of the Port Pelican Final Environmental Impact Statement (PPFEIS) and a broader and more comprehensive review of the potential impacts of developing other facilities that use flow through systems to warm LNG in the Gulf of Mexico. Our conclusion and recommendation is that these flow through systems should be avoided in favor of closed loop systems. The negative impacts to fishery species and living marine resources in the Gulf from a single flow-through facility are potentially severe, and cumulative impacts from multiple facilities must be considered a threat to fishery resources.

There is a special concern regarding the siting of flow through facilities in or near estuarine passes. Most fishery organisms in the Gulf of Mexico use estuaries as nursery grounds, and eggs and larvae recruit into these areas through tidal passes. Locating facilities in or near these tidal passes will be especially damaging to fishery resources, since eggs and larvae of fishery species are often concentrated in these areas. Locating LNG facilities in shallow water also increases the proportional area of impact. The area filtered per year can be calculated by combining average water depth with the expected intake volume of a facility. The sites farthest offshore only filter an area of about 2 km^2 per year, because of the water column depth (Table 1). In contrast, Sabine Lake, TX has an average depth of about 2 m, and the Golden Pass LNG site proposed for Sabine Pass will filter 69 km^2 each year. Sabine Lake has a surface area of 226 km^2 , a volume of about 0.45 km^3, and an average annual input of freshwater of 14.9 km^3 (Bianchi et al. 1999). The proposed facility in Sabine Pass will filter about 0.14 km^3 of water each year, or over 30% of the estuary's volume and about 1% of the inflow every year. Corpus Christi Bay (Nueces Estuary) has a surface area of 444 km^2 , a volume of about 1.33 km^3, and an average annual input of freshwater of only 0.77 km^3 (Bianchi et al. 1999). The proposed facility in the La Quinta Channel , filtering the same 0.14 km^3 of water each year, will filter 10% of the estuary's volume and about 18% of the inflow every year. In addition, the number of facilities being proposed should be considered, because cumulative impacts may be important. The locations of 13 LNG facilities in the Gulf of Mexico are shown in Figure 1 (not included); seven of these are flow through systems and six are closed loop systems (Table 1). Two additional LNG facilities have been identified, but we have limited information for them.

Table 1. Proposed Liquified Natural Gas processing facilities in the Gulf of Mexico

Name	Location	Expected Flow Rate Million Gal/day	Expected Flow Rate Million Gal/year	Water depth (m)	Area filtered per year (km^2)	Intake screen Size (mm)	Intake Flow Rate (ft/sec)
Vista del Sol LNG (ExxonMobil)		100	36,500	3	46.1	GunderBoom	0.2
Golden Pass LNG (ExxonMobil)		100	36,500	2	69.1	GunderBoom	0.2
El Paso Energy Bridge	° °	133	48,545	87	2.1	21	1
Shell Gulf Landing		136	49,640	16.8	11.2	6.35	0.5
Port Pelican	36 miles S-SW of Freshwater City, LA 29°01'33.41" N, 92 °32'11.85"W	176	64,240	25	9.7	6.35	0.5
Main Pass		100	36,500	64	2.2	6.35	0.5
ConocoPhillips ICE-T		200	73,000	22	12.6	6.35	0.5
ExxonMobil Offshore							
ExxonMobil							
Lake Charles (Trunkline) existing		Closed loop	n/a	n/a	n/a	n/a	n/a
Oxy-Chem		Closed loop	n/a	n/a	n/a	n/a	n/a
Freeport		Closed loop	n/a	n/a	n/a	n/a	n/a
Corpus Christi (Cheniere)		Closed loop	n/a	n/a	n/a	n/a	n/a
Cameron (Hackberry)	LA	Closed loop	n/a	n/a	n/a	n/a	n/a
Sabine Pass (Cheniere)	LA	Closed loop	n/a	n/a	n/a	n/a	n/a

One approach taken in examining the impact of these facilities on fishery species is to estimate the density of fish eggs and larvae in the water column near the facility and calculate the average number of planktonic organisms that are likely to pass through the facility and die based on seawater intake rates. Although we have attempted some of these calculations below, such calculations of egg and larvae density near facilities are

based on average values collected over relatively long time periods and integrated over the entire water column. The temporal and spatial distributions of these organisms, however, are extremely patchy. Thus, we should be aware and concerned about the possibility of a LNG facility being located just downstream from a spawning aggregation, because under these conditions a large portion of an entire cohort may be killed.

Port Pelican LNG Facility

The Port Pelican Liquid Natural Gas (LNG) processing facility is proposed for coastal Louisiana in 25 m (83 ft) of water. During Phase II of its operation, it is projected to take in 176.4 million gallons of seawater per day or 64.4 billion gallons per year. The water will be used to warm the LNG and will undergo a temperature decrease of 11^{o} C (20^{o} F). The intake rate will be around 15 cm/sec (0.5 ft/sec), allowing most larger organisms to avoid impingement at the intake structures, but water passing through the facility will undergo mechanical, pressure, temperature, and chemical (NaOCl) shock. Some entrained eggs and larvae may survive any one of these adverse conditions (Cada et al. 1981, Muessig et al. 1988), but the combination of these stresses will be lethal to almost all organisms passing through the facility. There is a long litany of research, supported by the electrical power industry, indicating that the mechanical damage associated with agitation and impact with impeller blades results in death to fish eggs and larvae. Although estimates of potential pressure flux are not given in the PPFEIS, rapid fluctuations in pressure are known to inflict, sub-lethal, antemortem, and lethal trauma on young fishes (Govoni et al. 2004). A temperature flux of 10°C would result in death of fish eggs and larvae (reviewed in Kamler, 1992), and the LD-50's listed for NaOCl in the PPFEIS for fishes are appropriate values. Until shown otherwise, we must assume that all fish and invertebrates will die after entrainment and simultaneous exposure to these four environment stress factors.

Impacts of Entrainment Mortality at Port Pelican on Fishery Stocks

Many questions need to be addressed about potential impacts of such a facility on the coastal ecosystem, and one of the most important is whether the entrainment and mortality of fish eggs and larvae at the facility will have significant population effects on fishery stocks. A stock assessment approach to this problem requires information on:

a) Numbers of eggs, larvae, and juveniles that are expected to be entrained (and killed) by species.
b) Daily natural mortality estimates by life stage during the first year of life by species, including hatching success. This allows an estimation of survival from viable egg to age of entrainment.
c) Age-structured population model (e.g., VPA or forward-projection model) estimates of recruits to age-1 and population fecundity (need maturity schedule and fecundity relationship). This allows stock-level estimates of egg production (viable eggs) and overall survival from viable egg to recruitment at age-1.

The specific data needed for such an in depth analysis are generally not available; stock assessments have been done for relatively few species,. In addition, such an effort would require a great amount of time from stock analysts, and when underlying density dependence is considered, the results may still not be clear cut. An alternative analysis could be based on the "near field" approach described by Boreman et al. (1981), Barnthouse and Van Winkle (1988), and Boreman and Goodyear (1988). This approach sidesteps some issues in (a) and (b) and develops direct estimates of relative loss. The approach does not attempt to make the final step of incorporating this loss into a population-level model. One problem would be how to characterize and assess the "near field".

We can make simplified calculations of the number of eggs and larvae entrained and killed in a LNG processing facility, but these estimates are based on many assumptions. For example at Port Pelican, SEAMAP data collected with oblique bongo net (0.333-mm mesh) tows were used to estimate fish egg and larvae densities. Average densities of 3.06 eggs per m^3 (14 samples) and 6.21 larvae per m^3 (32 samples) were obtained from cruises in June through November between 1984 and 1999 in a 30 nautical mile block around the proposed LNG facility site. These densities can be used to calculate that 1.13 billion eggs and larvae (Table 2) would pass through the facility under

Table 2. Density and entrainment estimates for plankton near the Port Pelican LNG facility in coastal Louisiana waters.

Data Source	No/m ^{3}	No/1million gallons water	Millions entrained during Phase II (176.4 MGD)
A. Original SEAMAP Data (June-November)			
Fish Eggs (14 samples)	3.06	11,583	373
Fish Larvae (32 samples)	6.21	23,507	757
Sum (Fish eggs+larvae)	9.27	35,091	1,130
B. SEAMAP estimate for (December-May)			
Fish Eggs	1.38	5,225	168
Fish Larvae	2.80	10,603	341
Sum (Fish eggs+larvae)	4.18	15,828	510
SEAMAP annual estimate (A+B)			
Fish Eggs			541
Fish Larvae			1,098
Sum (Fish eggs+larvae)			1,639
SEAMAP annual estimate adjusted for mesh selection, 3*(A+B)			
Fish Eggs			1,623
Fish Larvae			3,294
Sum (Fish eggs+larvae)			4,918
Shrimp larvae, annual estimate (Temple and Fischer 1967)	0.25	927	60
Zooplankton, annual estimate (Minello 1980)	2000	7,570,824	487,455

peak operating conditions (Phase II) during the summer and fall. Winter and spring densities, however, are lower (Ditty et al. 1988). At a station in coastal Louisiana waters closer to shore (10-12 m bottom depth), Ditty (1986) recorded average fish larvae densities to be 2.86 per m^3 in summer and fall and 1.29 per m^3 in winter and spring. Using this ratio of winter-spring : summer-fall densities, we can estimate densities and entrainment mortality (510 million eggs and larvae) during winter and spring at the Port Pelican site based on the SEAMAP data. Combining these data gives an annual mortality estimate of 1.6 billion eggs and larvae (Table 2). The density estimates for fish larvae from the SEAMAP samples (6.21 per m^3 in summer and fall) appear relatively high in comparison with other estimates in this general area of the northern Gulf of Mexico (Ditty, 1986, Sogard et al. 1987, Hernandez 2001), although differences in mesh size, distance from shore, season, and taxa examined exist among these studies. In contrast, however, concentrations of fish larvae as high as 10-90 per m^3 have been found in this area (Govoni, et al. 1989; Govoni and Grimes 1992; Govoni 1993) and in the northeastern Gulf (Govoni et al. 1985) associated with frontal zones or with the presence of petroleum drilling platforms (Hernandez 2001).

In addition to corrections needed for seasonality, there also is evidence that many small eggs and larvae can pass through the 0.333-mm mesh nets used in the SEAMAP collections. Comyns (1997) reported that catches of small red drum larvae were 5-8 times larger in a 0.202-mm mesh net compared with a 0.333-mesh net. Similarly, Houde and Lovdal (1984) found that larval fish densities in Biscayne Bay, FL collected in a 0.035-mm mesh net were 8.45 times larger than catches in a 0.333-mm mesh net towed simultaneously; this high extrusion rate was partly the result of active spawning in a coastal embayment, especially of bay anchovy and of the presence of soft bodied, recently hatched, and very small larvae (smaller than 2.5 mm in length). Despite the lack of specific data on net catch efficiency for SEAMAP estimates, some correction factor would appear necessary to adjust the mean densities at Port Pelican for eggs and larvae passing through the 0.333-mm mesh net. To provide a more realistic density estimate for eggs and larvae entrained, a multiplier of 3 was used in Table 2. These calculations convert to a best estimate of entrainment and mortality of *4.9 billion fish eggs and larvae each year.* Evidence for determining this multiplier is relatively weak, however, and multipliers from 1 to 8 could also be justified under different assumptions, resulting in estimates of entrainment between 1.6 and 13.1 billion eggs and larvae each year.

The larval fish taxonomic composition from the SEAMAP collections is shown in Table 3 and was used to estimate annual mortality of eggs and larvae for different fish taxa during Phase II, assuming that all entrained organisms at the Port Pelican LNG facility would die. Highest mortalities are estimated at 730 million eggs and larvae of carangids (jacks) each year, 693 million Engraulidae (anchovies), 496 million clupeids (herrings), and 495 million sciaenids (drum).

The PPFEIS concludes that mortality on the order of billions of eggs and larvae would have a minimal impact on fish populations based on the fecundity of individual fish. According to this approach, if the facility kills 13 million snapper eggs and larvae per year, and an adult snapper spawns 1 million eggs in a year, the facility only is harvesting the equivalent of 13 spawning females each year. This rationale is flawed and misleading. A single fish larva present in the water column is the product of many spawned eggs (hundreds to potentially thousands) depending upon larvae age and early life stage mortality rates.

Table 3. Entrainment estimates of eggs and larvae (in millions per year) for different Families and Orders of fishes based on the taxonomic composition of fish larvae collected in SEAMAP samples, annual mean densities adjusted for mesh selection in Table 2, and Phase II flow rate of 176.4 million gallons of seawater per day.

TAXON	Percent of larvae collected	Millions of eggs/year	Millions of larvae/year	Total eggs and larvae
Carangidae	14.84%	240.8	488.7	729.5
Engraulidae	14.09%	228.6	464.0	692.7
Unidentified Fish	13.94%	226.2	459.2	685.4
Clupeiformes	10.09%	163.7	332.3	496.0
Sciaenidae	10.07%	163.4	331.6	495.0
Cynoglossidae	8.32%	135.1	274.2	409.3
Gobiidae	8.05%	130.7	265.2	395.9
Clupeidae	6.32%	102.5	208.0	310.6
Paralichthyidae	4.69%	76.2	154.6	230.7
Scombridae	1.35%	22.0	44.6	66.6
Bregmacerotidae	1.32%	21.4	43.4	64.8
Ophidiidae	1.31%	21.2	43.1	64.3
Bothidae	1.20%	19.5	39.6	59.1
Serranidae	0.90%	14.7	29.7	44.4
Stromateidae	0.57%	9.2	18.6	27.8
Pleuronectiformes	0.56%	9.2	18.6	27.8
Ophichthidae	0.34%	5.5	11.1	16.6
Lutjanidae	0.27%	4.3	8.8	13.1
Triglidae	0.26%	4.2	8.5	12.6
Microdesmidae	0.23%	3.7	7.6	11.3
Perciformes	0.21%	3.5	7.0	10.5
Blenniidae	0.15%	2.4	4.8	7.2
Sphyraenidae	0.13%	2.1	4.3	6.4
Synodontidae	0.13%	2.1	4.2	6.3
Trichiuridae	0.13%	2.0	4.1	6.2
Pomatomidae	0.10%	1.6	3.3	4.9
Tetraodontidae	0.06%	1.0	2.0	3.1
Muraenidae	0.05%	0.9	1.8	2.7
Labridae	0.05%	0.8	1.7	2.5
Moringuidae	0.04%	0.6	1.2	1.8
Callionymidae	0.03%	0.6	1.1	1.7
Congridae	0.03%	0.5	0.9	1.4
Balistidae	0.02%	0.4	0.8	1.2
Anguilliformes	0.02%	0.3	0.6	0.9
Ephippidae	0.02%	0.3	0.6	0.9
Soleidae	0.02%	0.3	0.6	0.9
Scorpaenidae	0.02%	0.3	0.6	0.9
Syngnathidae	0.02%	0.3	0.5	0.8
Sparidae	0.02%	0.3	0.5	0.8
Scaridae	0.01%	0.2	0.4	0.6
Myctophidae	0.01%	0.2	0.3	0.5
Gerreidae	0.01%	0.1	0.3	0.4
Monacanthidae	0.01%	0.1	0.3	0.4
Uranoscopidae	0.01%	0.1	0.3	0.4

The problem of building a facility that increases fish egg and larvae mortality also can be viewed in a more general context. Mortality of fish eggs and larvae is already high, and stock success can depend on survival and transport of recruits to appropriate nursery habitats (Houde 1987, 1989). Many potential recruits are already lost because of environmental conditions, starvation, predation, or transport (current) variability. Mortality caused by LNG facilities is an additional mortality factor. If the facility kills the few recruits destined for survival, it may have a dramatic effect on a fish stock. Because the natural conditions that affect survival vary in time and space, it is highly unlikely that we will be able to determine the survival potential of eggs and larvae killed by entrainment. The variability in natural mortality, the uneven or patchy distribution of eggs and larvae, and the unknown effects of density dependent compensation in survival all contribute to uncertainty in estimating mortality or potential impacts of mortality from LNG facilities. The limited amount of information available on animal densities, distributions, and processes that influence survival does not support a conclusion that LNG facilities will have only minimal impacts on fishery stocks.

Entrainment of other Plankton at Port Pelican

Temple and Fischer (1967) estimated the distribution and abundance of shrimp larvae in the coastal waters off Galveston and western Louisiana; they examined monthly plankton data (oblique tows; 0.200-mm mesh) from 11 stations located from 14 m to 82 m in bottom depth. The total average catch of all stages of penaeid shrimp larvae from their samples over the entire study area provides an estimate of larval shrimp density in waters near the Port Pelican facility. This annual estimate of 0.245 larvae per m^3 converts to 59.7 million shrimp larvae entrained per year during Phase II (Table 2). There is substantial seasonal variability in the abundance of shrimp larvae, and 90% of the larvae were caught in the 4 months from August through November. Rogers et al. (1993) also sampled in coastal waters off Calcasieu Lake and obtained a mean density in nighttime tows of 0.05 brown shrimp postlarvae per m^3 from January through April.

In addition to decapod larvae, all zooplankton passing through the LNG facility are likely to be killed. A rough estimate from Minello (1980) indicates that average annual mesozooplankton densities (mostly copepods) are around 2000 per m^3 (0.200 mm mesh) in coastal waters off Texas and Louisiana. Zooplankton provide food for fish larvae, and at this density, 487 billion zooplankton per year would be entrained. *From another perspective, each year the facility would "sterilize" the entire water column for an area of 9.7 km^2 (2.7 square nautical miles) around the site (Table 1).*

Potential for Entrainment Mortality at Inshore Locations

Estuaries are important nurseries for many fishery species such as penaeid shrimps, blue crabs, gulf menhaden, Atlantic croaker, spot, southern flounder, spotted seatrout, and red drum. Many species spawn offshore or near estuarine passes, and larvae are seasonally concentrated in these passes. There is a large amount of literature on the migration of estuarine dependent species through tidal passes, but different sampling techniques, experimental designs, and project goals make comparisons among studies difficult. In Cedar Bayou, a tidal pass into Mesquite Bay, Texas, King (1971) found weekly average densities of penaeid shrimp postlarvae in March to reach as high as 300 per m^3 with an average density at his 5 stations of 16.3 per m^3 from January through April. Weekly mean densities of blue crab megalopae were recorded as high as 1000 per m^3 with an average density of 58.7 per m^3 from January through April. Lochman et al. (1995) reported average densities of crab larvae (mainly blue crab) in Matagorda Bay Ship Channel (a pass through Matagorda Island into Matagorda Bay, Texas) to be 2.5 per m^3 from April through August. Copeland and Truit (1966) reported highest densities of brown shrimp postlarvae in April at 0.75 per m^3 in Aransas Pass, Texas. Within one mile of Aransas Pass in the Gulf of Mexico, Holt et al. (1988) reported densities of red drum eggs from early September through mid-October as high as 20 per m^3 (more typically between 2-3 per m^3). Duronslet et al. (1972) collected penaeid shrimp postlarvae at different locations in the water column in Bolivar Roads, the pass into Galveston Bay, Texas, from November through April and reported a mean density of 0.37 brown shrimp postlarvae per m^3 from all nets. Hartman et al. (1987) identified 71 fish and 11 crustacean taxa from zooplankton samples taken in Keith Lake Pass near Sabine Lake, Texas using 0.505-mm mesh nets. Overall mean densities (number per m^3) for gulf menhaden, blue crab, white shrimp, and brown shrimp reported from their study were 1.0, 0.34, 0.20, and 0.08, respectively; but seasonal and interannual variation in the densities for most species was high. Highest densities occurred for gulf menhaden in spring 1986 (2.75 per m^3), in fall 1984 for blue crab (1.03 per m^3), in summer 1985 for white shrimp (0.73 per m^3), and in spring 1985 for brown shrimp (0.19 per m^3). Using seasonal densities and flow data, they estimated that Keith Lake Pass served as an immigration route for approximately 40 million brown shrimp, 116 million white shrimp, 314 million blue crab, 900 million gulf menhaden and 27 million Atlantic croaker annually. Densities of fish larvae in Oyster Bayou Pass into Fourleague Bay, Louisiana have been reported as high as 10-49 per m^3 (Raynie and Shaw 1994). Sampling monthly throughout the year, Ruple (1984) recorded average densities of fish larvae to be 308 per m^3 in the outer surf zone and 86 per m^3 in the inner surf zone off Horn Island, Mississippi. In Dog Keys Pass into Mississippi Sound between Horn Island and Ship Island, Lyczkowski-Shultz et al. (1990) collected fish larvae in January and May and reported an overall mean density around 1.5 per m^3. In Main Pass and Lower Mobile Bay, Marley (1983) reported mean densities of fish eggs to be over 100 per m^3. An obvious conclusion from these studies is that densities of crustacean and fish larvae (and fish eggs) in estuarine passes can be extremely high during some periods of the year. Variability is great both spatially and temporally. *These density patterns indicate an enormous potential for extensive entrainment mortality in and near estuarine passes.*

Ecosystem effects of filtering large volumes of water in estuarine passes also should be considered. In addition to the mortality of fish eggs and larval fish and crustaceans, most phytoplankton and zooplankton are likely to be killed in water passing through the facility. Densities of these organisms at inshore sites and in estuaries are generally much higher than in offshore waters (Minello 1980). These organisms are the base of the food web for many species in estuarine systems, and negative impacts on the estuarine food webs should be expected. Dissolved oxygen also may be reduced by a concomitant increase in detrital material in the system.

Entrainment versus Impingement

The swimming speeds of larval fishes vary greatly but are on average far less than the 15 cm/sec estimated as the velocity of water at the Port Pelican intake (see Hunter 1981, Johnston and Hall 2004, Osse and van den Boogaart 2004). Webb and Weihs (1986) reported swimming speeds as low as 0.03 cm/sec for early stage larvae. Even for settlement stage larvae, swimming speeds range between 7 to 21 cm/sec (Leis and Carson-Ewart 1997, 1999, Stobutzki and Bellwood 1997). Thus, most fish larvae and all eggs in the water column should truly be considered plankton and be expected to flow through facilities that take in seawater.

At least two of the proposed nearshore facilities plan to use Gunderboom's Marine Life Exclusion System, a "water-permeable barrier that keeps fish eggs, larvae and other aquatic organisms a safe distance away from an industrial intake structure" (Gunderboom, Inc. ; http://www.gunderboom.com/mls/mles.html). From internet searches, it appears that this technology has been used mainly in riverine systems and is unproven in eutrophic and often turbid estuarine systems such as those found on the Gulf coast. Seaby et al. (2002) reported fouling of Gunderboom material by bacteria, plants, and animals (including tube dwelling crustaceans) in Bowline Pond of the Hudson River Estuary where salinities range between 0.1 and 10 ppt. The loss of permeability was measured as a reduction in water flow through the fabric, and in panels of material not exposed to air-burst cleaning, permeability declined nonlinearly over time. After 20 days in Bowline Pond, flow across the fabric was reduced by 49%. After 29 days exposure, average flow was reduced by 62%. Air-burst cleaning increased fouling; and over a 30-day exposure period, the highest loss of permeability was 97% in a panel exposed to flowing water and air-burst cleaning. Seaby et al. (2002) concluded that fouling was likely to cause a failure of the system and result in entrainment of organisms. Fouling may be even greater in eutrophic estuarine systems. Cooling water in flow-through LNG facilities will have many similar impacts as warming water in electrical power generating facilities. Various cooling system alternatives and an assessment of entrainment problems for these facilities are reported by Tetra Tech (2002) and Riverkeeper (2003).

Planktonic fish eggs and small larvae not entrained will be impinged on permeable barriers regardless of the reduction of effective intake water velocity. As noted above in reference to net efficiencies, a mesh size of 0.333 mm can be expected to retain only a fraction of the eggs and larvae suspended in the water column. The estimate of Houde and Lovdal (1984) from Biscayne Bay, indicates that inshore, only about 10% of fish larvae may be retained by 0.333-mm mesh. Gunderboom aperture size, therefore, would have to be much smaller than 0.333 mm to prevent the entry of eggs and larvae. In the fouling experiment conducted by Seaby et al. (2002), Gunderboom fabric had an aperture size of 1 mm. In eutrophic and sediment laden water, fabric with an aperture size less than 0.333 mm would clog much more rapidly. Even if a small mesh size was used, and filtration efficiency could be maintained (i.e., no clogging), planktonic eggs and larvae would be impinged on the mesh surface and likely suffer mortality due to predation, starvation, or physical agitation. Aggregating predators are likely to feed upon impinged organisms, and air burst cleaning may damage any survivors.

Vertical Distribution of Larvae and Eggs near Port Pelican

Information on the vertical distribution of fish eggs and larvae in coastal waters of the northern Gulf of Mexico is limited, but patterns appear related to time of day, water column depth, and vertical stratification or stability. In deeper water, 100 to 200 m, fish eggs and larvae are more abundant in the upper 100 m. The shallower (25 m) water column of the proposed Port Pelican processing plant is likely to be hydrographically well mixed (at least in winter), and fish eggs and larvae should be more evenly dispersed in the water column. Govoni et al. (1985, 1989) and Sogard et al. (1987) sampled during winter, and fish larvae were well dispersed vertically (<100 m), unless the presence or passage of a frontal zone stratified the water column. Lyczkowski-Shultz and Steen (1991) sampled in September-October at three depths in coastal waters off Mississippi Sound (bottom depth was 18-25 m) and found red drum larvae concentrated in deeper waters at night and in the upper 5 m during the day. Temple and Fischer (1965) examined the vertical distribution of penaeid shrimp larvae at one station off Galveston, TX; when the water column was stable, they showed that larvae were more abundant at 18 and 34 m depths than at the surface (2 m). These data emphasize the inherent variability in distributions of marine organisms, the uncertainty involved in selecting a vertical strata to sterilize in the coastal ocean, and the need to avoid flow-through systems and entrainment mortality.

Potential Impacts of Discharge Water

A 0.5^{o} C decrease in water temperature 100 m from the discharge may still influence essential fish habitat by additively cooling the water where fish spawn and where fish eggs and larvae develop. This decrease in temperature will not be static, but cooled water will mix, the discharge will be continuous, and the water in the area as a whole will cool. Gonad maturation and spawning of fishes is controlled, in large part, by temperature. The rate of development of fish embryos and larvae is also controlled by temperature; cooler temperatures slow the rate of development and alter the mechanism of muscle development (e.g., Johnston and Hall, 2004). As development rate slows and larvae remain longer in early developmental stages, mortality increases (Houde 1987). Chlorination of the discharged water may also have detrimental effects on surrounding waters. The formation of many disinfectant by-products in addition to bromoform is likely (see WHO 2000), and fishery impacts of chronic exposure to these chemicals is unknown. The effects of discharging cooled and chlorinated water also may increase in relatively restricted tidal pass areas, as compared to offshore locations.

Literature Cited

Barnthouse, L. W. and W. Van Winkle 1988. Analysis of impingement impacts on Hudson River fish populations. p. 182-190 *In* Barnhouse, L. W., R. J. Klauda, D. S. Vaughan and R. L. Kendall (ed.). Science, law, and Hudson River power: a case study in environmental impact assessment. American Fisheries Society, Monograph 4, Bethesda.

Bianchi, T. S., J. R. Pennock and R. R. Twilley 1999. Biogeochemistry of Gulf of Mexico estuaries. New York, John Wiley and Sons, Inc.

Boreman, J., C. P. Goodyear and S. W. Christensen 1981. An empirical methodology for estimating entrainment losses at power plants sited on estuaries. Transactions of the American Fisheries Society 110: 253-260.

Boreman, J. and C. P. Goodyear 1988. Estimates of entrainment mortality for striped bass and other fish species inhabiting the Hudson River Estuary. p. 152-160 *In* Barnhouse, L. W., R. J. Klauda, D. S. Vaughan and R. L. Kendall (ed.). Science, law, and Hudson River power: a case study in environmental impact assessment. American Fisheries Society, Monograph 4, Bethesda.

Cada et al. 1981. p. 111-122 *In* Jensen, L. D. (ed.). Issues associated with impact assessments: Proceedings of the 5th national Workshop on Entrainment and Impingement.

Comyns, B. H. 1997. Growth and Mortality of Fish Larvae in the Northcentral Gulf of Mexico and Implications To Recruitment. Dissertation, Louisiana State University, 200 p.

Copeland, B. and Truitt 1966. Fauna of the Aransas Pass Inlet, Texas. II. Penaeid shrimp postlarvae. Tex. J. Sci. 18: 65-74.

Ditty, J. G. 1986. Ichthyoplankton in neritic waters of the northern Gulf of Mexico off Louisiana: Composition, relative abundance, and seasonality. Fish. Bull., U.S. 84: 935-46.

Ditty, J. G., G. G. Zieske and R. F. Shaw 1988. Seasonality and depth distribution of larval fishes in the northern Gulf of Mexico above latitude 26 degrees N. Fish. Bull., U.S. 86: 811-23.

Duronslet, M. J., J. M. Lyon and F. Marullo 1972. Vertical distribution of postlarval brown, Penaeus aztecus, and white, P. setiferus, shrimp during immigration through a tidal pass. Trans. Am. Fish. Soc. 101: 748-52.

Govoni, J. J., A. J. Chester, D. E. Hoss and P. B. Ortner 1985. An observation of episodic feeding and growth of larval Leiostomus xanthurus in the northern Gulf of Mexico. Journal of Plankton Research 7: 137-146.

Govoni, J. J., D. E. Hoss and D. R. Colby 1989. The spatial distribution of larval fishes about the Mississippi River plume. Limnol. Oceanogr. 34(1): 178-187.

Govoni, F. and C. Grimes 1992. The surface accumulation of larval fishes by hydrodynamic convergence within the Mississippi River plume front. Cont. Shelf Res.12: 1265-1276.

Govoni, J. J. 1993. Flux of larval fishes across frontal boundaries - examples from the Mississippi river plume front and the western gulf stream front in winter. Bull Mar Sci 53: 538-566.

Govoni, J. J. 2004. The development of form and function in fishes, and the question of larval adaptation. Bethesda, MD, American Fisheries Society. Amer. Fish. Soc. Symp 40**:**

Hartman, R. D., C. F. Bryan and J. W. Korth 1987. Community structure and dynamics of fishes in a Southeast Texas estuary. U.S. Fish and Wildlife Service, Albuquerque. 116 p.

Hernandez, F. J., Jr. 2001. The across-shelf distribution of larval, postlarval, and juvenile fishes collected at oil and gas platforms and a coastal jetty off Louisiana west of the Mississippi River delta. Ph.D. Dissertation, Louisiana State University,

Holt, S. A., G. J. Holt and C. R. Arnold 1988. Distribution of eggs and larvae of red drum (*Sciaenops ocellatus*) in Texas coastal waters. Cont. Mar Sci. 30: 196.

Houde, E. D. and J. A. Lovdal 1984. Seasonality of occurrence, foods and food preferences of ichthyoplankton in Biscayne Bay, Florida. Estuarine, Coastal and Shelf Science 18: 403-419.

Houde, E. D. 1987. Fish early life dynamics and recruitment variability. p. 17-29 *In* Hoyt,

R. D. (ed.). Proceedings of the10th Annul Larval Fish Conference held in Miami, FL May 18-23, 1986. American Fisheries Society Symposium 2. American Fisheries Society, Bethesda, MD.
Houde, E. 1989. Subtleties and episodes in the early life of fishes. J. Fish. Biol. 35 Supplement A: 29-38.
Hunter, J. R. 1981. Feeding ecology and predation of marine fish larvae. p. 33-79 *In* Lasker, R. (ed.). Marine fish larvae: morphology, ecology, and relation to fisheries. University of Washington Press,
Johnston, I. A. and Hall 2004. Mechanisms of muscle development and responses to temperature changes.. ,. p. 85-116 *In* Govoni, J. J. (ed.). The development of form and function in fishes, and the question of larval adaptation. American Fisheries Society, Bethesda, MD.
Kamler, E. 1992. Early life history of fish: an energetics approach. Chapman and Hall Fish and Fisheries Series 4.
King, B. D. 1971. Study of migratory patterns of fish and shellfish through a natural pass. TPWD, Tech. Ser. No. 9: 1-54.
Leis, J. M. and B. M. Carson-Ewart 1997. In situ swimming speeds of the late pelagic larvae of some Indo-Pacific coral-reef fishes. Mar. Ecol. Prog. Ser. 159: 165-174.
Leis, J. M. and B. M. Carson-Ewart 1999. In situ swimming and settlement behaviour of larvae of an Indo-Pacific coral-reef fish, the coral trout *Plectropomus leopardus* (Pisces: Serranidae). Mar. Biol. 134: 51-64.
Lochmann, S. E., R. M. Darnell and J. D. Mceachran 1995. Temporal and vertical distribution of crab larvae in a tidal pass. Estuaries 18: 255-263.
Lyczkowski-Shultz, J., D. L. Ruple, S. L. Richardson and J. H. Cowan, Jr 1990. Distribution of fish larvae relative to time and tide in a Gulf of Mexico barrier island pass. Bull. Mar. Sci. 46: 563-577.
Lyczkowski-Shultz, J. and J. Steen, Jr 1991. Diel vertical distribution of red drum *Sciaenops ocellatus* larvae in the north central Gulf of Mexico. Fishery Bulletin 89: 631-641.
Marley, R. D. 1983. Spatial distribution patterns of planktonic fish eggs in lower Mobile Bay, Alabama. Trans. Amer. Fish. Soc. 112: 257-266.
Minello, T. J. 1980. The neritic zooplankton of the northwestern Gulf of Mexico. Texas A&M University, College Station, 240 p.
Muessig, P. H., J. R. Younf, D. S. Vaughan and B. A. Smith 1988. Advances in field and analytical methods for estimating entrainment mortality factors. p. 124-132 *In* Barnhouse, L. W., R. J. Klauda, D. S. Vaughan and R. L. Kendall (ed.). Science, law, and Hudson River power: a case study in environmental impact assessment. American Fisheries Society, Monograph 4, Bethesda.
Osse, J. W. M. and J. G. M. van den Boogart 2004. Allometric growth in fish larvae: timing and function. p. 167-194 *In* Govoni, J. J. (ed.). The development of form and function in fishes, and the question of larval adaptation. American Fisheries Society, Bethesda, MD.
Raynie, R. C. and R. F. Shaw 1994. A comparison of larval and postlarval gulf menhaden, *Brevoortia patronus*, growth rates between an offshore spawning ground and an estuarine nursery. Fish Bull 92: 890-894.
Riverkeeper, I. 2003. Comprehensive survey and investigation of dry cooling systems to reduce impingement and entrainment. Riverkeeper, Inc. (http://riverkeeper.org/campaign.php/fishkills/we_are_doing/622),

Rogers, B. D., R. F. Shaw, W. H. Herke and R. H. Blanchet 1993. Recruitment of postlarval and juvenile brown shrimp (*Penaeus aztecus* Ives) from offshore to estuarine waters of the northwestern Gulf of Mexico. Estuarine, Coastal and Shelf Science 36: 377-394.

Ruple, D. L. 1984. Occurrence of larval fishes in the surf zone of a northern Gulf of Mexico barrier island. Estuarine, Coastal and Shelf Science 18: 191-208.

Seaby, R. M., P. A. Henderson, C. Cailes and J. R. Somes 2002. Gunderboom fouling studies. (http://riverkeeper.org/document.php/138/Appendix_C__Pis.pdf). Pices Conservation Ltd (www.irchouse.demon.co.uk), England.

Sogard, S. M., D. E. Hoss and J. J. Govoni 1987. Density and depth distribution of larval gulf menhaden, Brevoortia patronus , Atlantic croaker, Micropogonias undulatus , and spot, Leiostomus xanthurus , in the northern Gulf of Mexico. Fishery Bulletin 85: 601-609.

Stobutzki, I. and D. R. Bellwood 1997. Sustained swimming abilities of the late pelagic stages of coral reef fishes. Mar. Ecol. Prog. Ser. 149: 1-3.

Temple, R. F. and C. C. Fischer 1965. Vertical distribution of planktonic stages of penaeid shrimp. Publ. Inst. Mar. Sci. Univ. Texas 10: 59-67.

Temple, R. F. and C. C. Fischer 1967. Seasonal distribution and relative abundance of planktonic-stage shrimp (Penaeus spp.) in the northwestern Gulf of Mexico, 1961. Fish. Bull., U.S. 66: 323-334.

Tetra Tech 2002. Evaluation of cooling system alternatives - proposed Morro Bay power plant. Tetra Tech, Inc. (http://www.swrcb.ca.gov/rwqcb3/MorroBayDNA/Reports/TetraTechMBPP.pdf),

Webb, P. W. and D. Weihs 1986. Functional locomotor morphology of early life history stages of fishes. Transactions of the American Fisheries Society 115: 115-127.

WHO 2000. United Nations Environment Programme, International Labour Organisation, World Health Organization, International Programme On Chemical Safety. Environmental Health Criteria 216. Disinfectants And Disinfectant By-Products. http://www.inchem.org/documents/ehc/ehc/ehc216.htm: